

1 We claim:

2 1. A magnetic recording medium comprising:

3 a substrate;

4 a lower magnetic layer structure formed over said substrate, said lower magnetic

5 layer structure exhibiting a Ms greater than 250 emu/cm<sup>3</sup>;

6 an intermediate layer comprising Ru; and

7 an upper magnetic layer structure formed over said intermediate layer, said upper

8 magnetic layer structure being antiferromagnetically coupled to the lower magnetic layer

9 structure.

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11 2. Magnetic recording medium of claim 1 wherein the Ms of the lower magnetic

12 layer structure is greater than 300 emu/cm<sup>3</sup>.

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14 3. Magnetic recording medium of claim 1 wherein said lower magnetic layer

15 structure comprises a layer comprising mostly Co, between 5 and 20 at. % Cr, 0 to 6 at.

16 % Ta, 0 to 10 at. % B and 0 to 10 at. % Pt.

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18 4. Magnetic recording medium of claim 3 wherein said layer of said lower magnetic

19 layer structure comprises between 0 and 10 % X, where X is one or more elements other

20 than Co, Cr, Ta, B or Pt.

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22 5. Magnetic recording medium of claim 4 wherein X comprises one or more of Nb,

23 Ta, Cu, Mo, W, V, Si, C, Pd, Ru, Ir or Y.

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2     6.     Magnetic recording medium of claim 1 wherein the upper magnetic layer  
3     structure comprises a layer comprising mostly Co, between 10 and 30 at. % Cr, between  
4     8 and 20 at. % Pt, and 0 to 20 at. % B.

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6     7.     Magnetic recording medium of claim 6 wherein said layer of said upper magnetic  
7     layer structure comprises between 0 and 10 at. % X, wherein X is one or more elements  
8     other than Co, Cr, Pt or B.

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10    8.     Magnetic recording medium of claim 7 wherein X comprises one or more  
11    elements selected from Nb, Ta, Cu, Mo, W, V, Si, C, Pd, Ru, Ir or Y.

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13    9.     The magnetic recording medium of claim 1 further comprising an underlayer  
14    formed between the substrate and the lower magnetic layer structure.

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16    10.    The magnetic recording medium of claim 1 wherein at least one of said upper and  
17    lower magnetic layer structures comprise a plurality of layers.

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19    11.    The magnetic recording medium of claim 1 wherein a lowest magnetic layer  
20    structure is formed above said substrate, a second intermediate layer comprising Ru is  
21    formed between said lowest magnetic layer structure and said lower magnetic layer  
22    structure, and said lowest magnetic layer structure is antiferromagnetically coupled to  
23    said lower magnetic layer structure.

- 1
- 2 12. A magnetic disk drive comprising the magnetic recording medium of claim 1.
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- 4 13. A magnetic disk comprising:
- 5       a substrate;
- 6       a lower magnetic layer structure formed over the substrate;
- 7       an intermediate layer comprising Ru;
- 8       an upper magnetic layer structure formed over the intermediate layer, said upper
- 9       magnetic layer structure being antiferromagnetically coupled to the lower magnetic layer
- 10      structure, wherein the relationship between the dynamic coercivity of the lower magnetic
- 11      layer structure and the exchange field is such that during writing a portion of the lower
- 12      magnetic layer structure achieves substantially its steady magnetization state within the
- 13      time required for one revolution of said disk.
- 14
- 15 14. The magnetic disk of claim 13 wherein at least one of said upper and lower
- 16      magnetic layer structures comprise a plurality of layers.
- 17
- 18 15. The magnetic disk of claim 13 wherein a lowest magnetic layer structure is
- 19      formed above said substrate, a second intermediate layer comprising Ru is formed
- 20      between said lowest magnetic layer structure and said lower magnetic layer structure, and
- 21      said lowest magnetic layer structure is antiferromagnetically coupled to said lower
- 22      magnetic layer structure.

1       16.    Magnetic disk of claim 13 wherein said magnetic disk is incorporated into a disk  
2       drive, said magnetic disk rotating.

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4       17.    A magnetic disk comprising:  
5              a substrate;  
6              a lower magnetic layer structure formed over the substrate;  
7              an intermediate layer comprising Ru; and  
8              an upper magnetic layer structure formed over the intermediate layer, said upper  
9       magnetic layer structure being antiferromagnetically coupled to the lower magnetic layer  
10      structure, wherein the relationship between the dynamic coercivity of the lower magnetic  
11      layer structure and the exchange field is such that during writing a portion of the lower  
12      magnetic layer structure achieves more than 90% of its steady magnetization state within  
13      the time required for one revolution of said disk.

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15       18.    A magnetic disk comprising:  
16              a substrate;  
17              a lower magnetic layer structure formed over the substrate;  
18              an intermediate layer comprising Ru; and  
19              an upper magnetic layer structure formed over the intermediate layer, said upper  
20      magnetic layer structure being antiferromagnetically coupled to the lower magnetic layer  
21      structure, wherein the relationship between the dynamic coercivity of the lower magnetic  
22      layer structure and the exchange field is such that during writing a portion of the lower

1       magnetic layer structure achieves more than 95% of its steady magnetization state within  
2       the time required for one revolution of said disk.

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4       19.     A magnetic recording medium comprising:  
5              a substrate;  
6              a lower magnetic layer structure formed over the substrate;  
7              an intermediate layer comprising Ru; and  
8              an upper magnetic layer structure formed over the intermediate layer, said upper  
9        magnetic layer structure being antiferromagnetically coupled to the lower magnetic layer  
10      structure, wherein the relationship between the dynamic coercivity of the lower magnetic  
11      layer structure and the exchange field is such that during writing a portion of the lower  
12      magnetic layer structure achieves substantially its steady magnetization state within 100  
13      milliseconds.

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15       20.     A magnetic recording medium comprising:  
16              a substrate;  
17              a lower magnetic layer structure formed over the substrate;  
18              an intermediate layer comprising Ru; and  
19              an upper magnetic layer structure formed over the intermediate layer, said upper  
20      magnetic layer structure being antiferromagnetically coupled to the lower magnetic layer  
21      structure, wherein the relationship between the dynamic coercivity of the lower magnetic  
22      layer structure and the exchange field is such that during writing a portion of the lower

1       magnetic layer structure achieves more than 90% of its steady magnetization state within  
2       100 milliseconds.

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4       21.     A magnetic recording medium comprising:  
5               a substrate;  
6               a lower magnetic layer structure formed over the substrate;  
7               an intermediate layer comprising Ru; and  
8               an upper magnetic layer structure formed over the intermediate layer, said upper  
9       magnetic layer structure being antiferromagnetically coupled to the lower magnetic layer  
10      structure, wherein the relationship between the dynamic coercivity of the lower magnetic  
11      layer structure and the exchange field is such that during writing a portion of the lower  
12      magnetic layer structure achieves more than 95% of its steady magnetization state within  
13      100 milliseconds.

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15       22.     Magnetic recording medium comprising:  
16               a substrate;  
17               a lower magnetic layer structure formed over said substrate, said lower magnetic  
18      layer structure having a Ku between 0 and  $10^6$  erg/cm<sup>3</sup>;  
19               an intermediate layer comprising Ru formed over the lower magnetic layer  
20      structure; and  
21               an upper magnetic layer structure formed over said intermediate layer, said upper  
22      magnetic layer structure being antiferromagnetically coupled to said lower magnetic layer  
23      structure and having a Ku greater than  $10^6$  erg/cm<sup>3</sup>.

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2    23.    Magnetic recording medium of claim 22 wherein said lower magnetic layer  
3    structure has a Ku less than  $0.5 \times 10^6$  erg/cm<sup>3</sup>.

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5    24.    The magnetic recording medium of claim 22 wherein at least one of said upper  
6    and lower magnetic layer structures comprise a plurality of layers.

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8    25.    The magnetic recording medium of claim 22 wherein a lowest magnetic layer  
9    structure is formed above said substrate, a second intermediate layer comprising Ru is  
10   formed between said lowest magnetic layer structure and said lower magnetic layer  
11   structure, and wherein said lowest magnetic layer structure is antiferromagnetically  
12   coupled to said lower magnetic layer structure.

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14   26.    A magnetic disk drive comprising the magnetic recording medium of claim 22.

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16   27.    A magnetic recording medium comprising:

17              a lower magnetic layer structure;

18              an intermediate layer comprising Ru formed over the lower magnetic layer  
19   structure; and

20              an upper magnetic layer structure antiferromagnetically coupled to the lower  
21   magnetic layer structure and formed over said intermediate layer, the dynamic coercivity  
22   of the lower magnetic layer structure being greater than or equal to zero but less than the  
23   exchange field between the upper and lower magnetic layer structures.

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2 28. Magnetic recording medium of claim 27 wherein said dynamic coercivity of said  
3 lower magnetic layer structure is less than one half of the exchange field.

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5 29. Magnetic recording medium of claim 27 wherein said dynamic coercivity is for a  
6 recording switching time between 1 and 10 ns.

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8 30. The magnetic recording medium of claim 27 wherein at least one of said upper  
9 and lower magnetic layer structures comprise a plurality of layers.

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11 31. The magnetic recording medium of claim 27 wherein a lowest magnetic layer  
12 structure is formed above said substrate, a second intermediate layer comprising Ru is  
13 formed between said lowest magnetic layer structure and said lower magnetic layer  
14 structure, and said lowest magnetic layer structure is antiferromagnetically coupled to  
15 said lower magnetic layer structure.

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17 32. A magnetic disk drive comprising the magnetic recording medium of claim 27.

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19 33. Magnetic recording medium comprising:

20 a substrate;

21 a lower magnetic layer structure formed over said substrate;

22 an intermediate layer comprising Ru formed over said lower magnetic layer; and

1           an upper magnetic layer structure formed over said intermediate layer, said upper  
2       magnetic layer being antiferromagnetically coupled to said lower magnetic layer  
3       structure, the coercivity of said lower magnetic layer structure as measured in a switching  
4       time of 10 milliseconds being less than the exchange field between said upper and lower  
5       magnetic layer structures.

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7       34.      Magnetic recording medium of claim 33 wherein said coercivity of said lower  
8       magnetic layer structure as measured in a switching time of 10 milliseconds is less than  
9       one half of the exchange field between said upper and lower magnetic layer structures.

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11       35.      The magnetic recording medium of claim 33 wherein at least one of said upper  
12       and lower magnetic layer structures comprise a plurality of layers.

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14       36.      The magnetic recording medium of claim 33 wherein a lowest magnetic layer  
15       structure is formed above said substrate, a second intermediate layer comprising Ru is  
16       formed between said lowest magnetic layer structure and said lower magnetic layer  
17       structure.

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19       37.      A magnetic disk drive comprising the magnetic recording medium of claim 33.

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21       38.      Magnetic recording medium comprising:  
22            a substrate;

1           a lower magnetic structure formed over said substrate, said lower magnetic  
2         structure comprising a magnetically soft material with intergranular decoupling;  
3           an intermediate layer comprising Ru formed over said lower magnetic layer  
4         structure; and  
5           an upper magnetic layer structure formed over said intermediate layer, said upper  
6         magnetic layer structure being antiferromagnetically coupled to said lower magnetic layer  
7         structure.

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9         39.      Magnetic recording medium of claim 38 wherein said lower magnetic layer  
10         structure comprises an alloy selected from the list consisting of permalloy, sendust,  
11         CoTaZr, FeTaC, NiFeNb, CoFe, NiCrFe, NiV, CuNi, FeRh and PtMn.